BOARD OF AGRICULTURE AND FISHERIES.

F. J. Brooks

POTATO DISEASE ("BLIGHT")

AND

ITS PREVENTION.

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FOOD PRODUCTION DEPARTMENT,
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POTATO DISEASE ("BLIGHT") AND ITS PREVENTION.

I.—HISTORY OF THE DISEASE.

The common potato disease known as "blight" or "late blight" is caused by a minute (microscopic) form of vegetable life—the parasitic fungus *Phytophthora infestans*. It was first noticed in Europe and America about 1840, and by 1845 it had become widespread. In the latter year "blight" was so virulent in Ireland that it caused an almost complete failure of the potato crop, with consequent famine to the inhabitants.

Since that time the disease has always been present in the British Isles, varying in intensity from year to year: more disastrous in its effects in wet seasons, less serious in dry seasons. In a wet summer losses of more than half the crop may be caused by this disease where precautions are not taken to prevent it, and even in an average season it takes a considerable toll of the tubers.

II.—SYMPTOMS.

The first sign of the disease visible to the naked eye is the appearance on the leaves of dark brown or blackish spots of irregular size and shape, on the under surface of which a delicate white mould may be seen, especially round the margin of the diseased areas. If weather conditions favour the "fungus" the dark coloured patches spread rapidly and the whole of the foliage, and sometimes the stems also, soon become blackened.

Potato plants badly attacked by "blight" give off a very distinct and disagreeable smell. In wet, muggy weather the whitish mould, which is the most characteristic sign of the disease, may grow out from the upper as well as from the under surface of the leaves. The minute threads, of which the whitish mould consists, branch like microscopic trees and produce innumerable, pear-shaped outgrowths, the spores or "seeds" of the fungus. The spores becoming detached from the thread-like stalks which bear them, are carried by currents of air and spread the disease to any healthy potato leaves on which they happen to alight. Each spore falling on a leaf, growing into and spreading through it, gives rise to a discoloured patch. After the fungus has fed on the food substances in the leaf, its threads grow out from the leaf into the air, especially from the under surface, and form the whitish mould already described. The period from the time of infection to the production of a new crop of spores is only a few hours, or at the most days, hence the extreme rapidity with which the disease may spread. If dry weather intervenes after a bad attack of "blight," the affected leaves shrivel and subsequently fall off, leaving the haulm bare.

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If the weather is wet after the haulm has been attacked, the tubers soon begin to be affected. Infection of the tubers is brought about by spores which, liberated from the surface of the leaf, are washed down into the soil. The first signs of disease in the tubers are discoloured, rusty patches just visible through the skin but more evident when the skin is scraped away. At first only a small part of the tuber may be attacked, but the disease may spread rapidly until half or more of the tuber is affected. Blighted tubers may also become secondarily infected with bacteria and other micro-organisms, when a soft rot sets in, which reduces the tubers to the consistency of pulp.

The re-appearance of "blight" year after year is mainly due to the fact that each year a certain number of tubers infected with the disease are planted as "seed." This in turn is due to the fact that slightly infected tubers are easily overlooked. Herein lies the advantage of "boxing" tubers, for if boxed the diseased tubers may very often be detected by the fact that they either do not sprout at all or bear poor and weakly sprouts. Such sets should not be planted. When small quantities of "boxed" potatoes are to be planted, it is advisable to cut across the tubers at planting time and to observe whether the flesh shows hollow spaces or black or brown spots. Any such tubers should be regarded as suspect and should not be planted. To prevent any possible damage from cutting, the cut surface may be rubbed in dry plaster of Paris, powdered lime, sulphur, or charcoal dust. Under suitable weather conditions during the early part of the summer, some of the slightly diseased tubers, that escaped detection at the time of planting, may give rise to one or more diseased shoots which come above ground and on which spores develop, thus providing the starting point for an epidemic. Potato "blight" develops its spores and hence spreads most rapidly under moist conditions, such as are provided by warm, muggy days following heavy rain.

Infection may perhaps also proceed from diseased tubers which have been left in the ground after digging, or which have lain about near clamps during the winter. No satisfactory evidence is yet forthcoming that the disease persists during the winter in a dormant condition in the soil.

III.—THE EPIDEMIC OF 1917.

Exact information of the progress and spread of "blight" during the summer would be of great value.

It has been shown already that the disease may develop very rapidly in a given plot or field, but it is not known exactly at what rate the disease develops over the country-side. With the object of obtaining information of this nature, records were collected in 1917 by the Food Production Department of the dates at which the disease was first reported in various localities. The dates given may be taken to represent the times at which the disease was fairly conspicuous, and it must be remembered that the inconspicuous early stages must in many cases have

escaped notice. Incomplete as the records are, they show several noteworthy features.

The earliest records were obtained from Cornwall, where "blight" was reported in the Penzance district as occurring on early varieties *at the end of May*. In the inland parts of Cornwall the first records came from the neighbourhood of Truro, in which district "blight" was reported in the middle of June. On June 20th specimens of the disease were received from Fishguard (Pembrokeshire) and from near Ryde in the Isle of Wight. Thus the disease made its appearance about the same time in widely separated districts, all of them with the humid climate characteristic of western and southern sea-board places. It is noteworthy that already before this date the disease had made its appearance in Ireland.

By the beginning of July disease had broken out in North Devon, and shortly afterwards reports of the occurrence of "blight" were received from Somerset (Taunton) and Dorset (Maiden Newton). In Devon in particular the disease, when it broke out, appeared in many different centres, and at Kingsbridge and Barnstaple "blight" was virulent on unsprayed areas during the second half of July.

The disease was seen in Holy Island on July 10th, and in Anglesey on July 16th.

In the eastern half of England during the early part of July the weather was generally dry, and the only recorded trace of disease was one in Bedfordshire, at Maulden, on July 8th.

"Blight" appeared in Wiltshire (Salisbury) on July 18th, and outbreaks afterwards became general in the county.

On July 26th "blight" was reported in Berkshire (Maidenhead), and a few days later in Buckinghamshire (Wooburn Green), and Northamptonshire. The exceptionally heavy rains during the week commencing July 29th favoured the development of the disease, and during this period many reports were received of the presence of "blight" in the Valley of the Thames. During this wet spell the disease became very general over the southern counties, and the areas now affected included, in addition to those already mentioned, Hampshire, Sussex, Surrey, Kent, Gloucestershire, Worcestershire, Monmouthshire, Glamorganshire, Carmarthenshire, Carnarvonshire, and Denbighshire, and shortly afterwards Herefordshire, Shropshire, Breconshire, Radnorshire, Cardiganshire, Montgomeryshire, Merionethshire, Huntingdonshire, Rutland, Derbyshire, and Nottinghamshire.

During the first week of August cases of "blight" were found also in the London area at Richmond and in other western suburbs, also in Hertfordshire; but its appearance in the southern and eastern districts of London was not reported until a week or more later.

During the second week of August "blight" became evident in Essex, Suffolk, Norfolk, Cambridgeshire, Lincolnshire, Leicestershire, Warwickshire and Staffordshire.

It was not until the third week of August that reports were received of the outbreak of disease in the more northerly counties, when it appeared in Flint, Cheshire, Lancashire, Yorkshire, Durham, and Northumberland. By this time, in fact, it may be said that the disease was generally distributed over the country.

Hence it will be seen that the development of the disease over the country as a whole was, generally speaking, in two main directions, one from the south-western end of England, developing fanwise and progressively over the counties, roughly speaking, south of the line drawn from the Bristol Channel to the Wash, and the other developing through the Welsh counties in a somewhat irregular manner.

A point of considerable practical importance is the fact which the records make clear, that there is a well marked interval of time between the date of the first recorded appearance in a county and that at which the disease is seen to be widespread. For example, the record for Somersetshire shows:—

Disease first reported, 7th of July.
Disease widespread, the end of July.

The importance of the observation lies in the fact that the first recorded outbreak gives a hint to those who have not already sprayed that no time should be lost before adopting this means of protection. Needless to say, however, the first spraying should have been done before that time if prevention is to be ensured.

As is to be expected, disease usually appears on elevated land at a later date than on low-lying land in the same district.

There is evidence that "blight" appears on early and second early varieties before it develops on late ones. Indeed, it may be said that "blight" is a "disease of middle age," that is to say, it is not until a certain advanced stage of growth has been reached that the potato plant becomes susceptible to the disease. Thus at Merton, "blight" which appeared first on "British Queen" (a second early variety) on August 2nd, did not develop on late varieties until August 24th. This indicates that the age of the foliage is an important factor in the incidence of this disease.

Another noteworthy feature of the epidemic in 1917 is the fact that the disease appeared nearly two months later in the north than in the south-west of England. It may also be worth mentioning, although too much emphasis must not be laid on the observation, that the general direction of the development of the disease, namely, towards the east and north, was that of the prevailing winds. More important, however, is the fact that in every, or in almost every case, the appearance of the disease was heralded by a spell of wet weather.

As to the virulence of the disease, it can only be said that it varied greatly in different districts, and that the counties which appear to have suffered most are Devon, Somerset, Hampshire, Dorset and Kent.

IV.—THE PREVENTION OF "BLIGHT" BY SPRAYING.

The object of spraying potatoes is to prevent the outbreak and spread of "blight," and in order to do this it is necessary to use a substance which, whilst not harmful to the potato plant, prevents the fungus which causes "blight" from penetrating into the tissues of the leaves. The substance, if it is to be effective, must not only have this property but also must be capable of adhering firmly to the leaf.

A solution of copper sulphate, if used alone, though it would destroy the blight fungus, would also injure the foliage. When, however, copper sulphate is combined with lime or washing soda, a fungicide is obtained which is both harmless to the potato foliage and destructive to the fungus. The use of Bordeaux mixture (copper sulphate combined with lime) and Burgundy mixture (copper sulphate combined with washing soda) has been common for many years in the vineyards of France and other countries. These substances have also been used largely and for many years for the purpose of preventing "blight" in potatoes, and it has been shown that the more effectively the foliage is covered with either of these mixtures, the more thoroughly is an outbreak of "blight" prevented.

By the use of Bordeaux or Burgundy mixture, the spores of the fungus are prevented from germinating and producing threads which grow into the tissues of the leaf, and hence the haulm, instead of withering, as it does when attacked by "blight," remains healthy and green; as a consequence the weight of the crop is increased and the tubers remain free from "blight."

In practice, however, no matter how carefully spraying may be done, it is not possible to cover the foliage so completely as to prevent all chance of infection. But even so, spraying when well done assists very materially in preventing the successive and rapid infections already described, and hence in limiting the extent of the disease both in the haulm and in the tubers.

It is important to realise that spraying is to be regarded as a means of prevention rather than as a cure, for when this is realised it becomes apparent first, that spraying must be done in good time and second, that if heavy rains have washed the spraying material from the leaves, the operation of spraying must be repeated. This is the more important because in wet seasons the fungus finds conditions favourable for its rapid multiplication, so that if wet weather follows the spraying it is doubly important to repeat the operation, and even to spray a third time. Some of the most successful large growers of potatoes no longer rely on spraying only once or twice, but make a practice of spraying as often as the weather conditions make the repetition of spraying necessary.

In short, spraying must not be regarded as an infallible preventive of "blight." It is not. Spraying should rather be regarded as a measure of insurance: as a means of enabling the plant to tide over a time during which it is specially liable to

infection, and if by reason of spraying this dangerous time is successfully passed, the work of tuber-formation goes on instead of being checked, as would be the case if the disease got a hold on the plant. Hence the yield is increased, and the proportion of sound tubers is larger than would be obtained from a crop the tops of which have been attacked by disease.

Later on, if the disease declares itself in the tops when tuber formation is approaching completion, and when, owing to the large growth of the haulm, spraying is no longer possible, removal of the tops will help to prevent the fungus from infecting the tubers in the ground.

The accumulated evidence of many years justifies the conclusion that the cost of insurance by spraying in an average season is amply repaid by the greater yield of healthy tubers.

It may be of interest to mention briefly the views held by scientific men as to the way in which Bordeaux mixture acts. One is that the carbon-dioxide in the air acts upon Bordeaux mixture in such a way as to bring about the gradual liberation of small amounts of soluble copper, which substance, though present at any given time in very small quantities, is sufficient to kill the spores of the blight fungus. Another view is that the spores falling upon the film of Bordeaux mixture excrete a substance which acts upon the mixture, and brings about the liberation of soluble copper. By absorbing this, the fungus brings about its own death by poisoning. The action of Burgundy mixture is probably identical with that of Bordeaux mixture.

Opinions differ as to the relative value of Bordeaux and Burgundy mixtures; there is, however, no doubt but that both are efficient fungicides. Where freshly burnt, stone-lime of good quality is to be obtained the use of Bordeaux mixture is to be recommended; but in districts where good lime is not readily to be had, Burgundy mixture should be used.

V.—INSTRUCTIONS FOR MAKING BURGUNDY MIXTURE.

The mixture should be carefully made, otherwise injury to the foliage may result. It is essential that all the soluble copper be precipitated by the addition of sufficient soda. Whilst adding the soda to the solution of copper sulphate the mixture must be vigorously stirred. The precipitate formed by the mingling of these two substances should be flocculent and should remain in suspension for a considerable time. Before use, the mixture should be tested with litmus paper.* If a piece of red litmus paper dipped into the mixture remains red, more soda in solution should be added gradually and the mixture again stirred until it is found that a fresh piece of litmus paper *just* turns blue.

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* Packets of red litmus paper may be obtained from the local chemist's shop at small cost.

FIG. 1. Under surface of a potato leaf attacked by "blight."

FIG. 2. Upper surface of a potato leaf attacked by "blight."

The method of making Burgundy mixture is as follows:—

For Spraying 1/3 Acre (say 50 rods).

(1) Dissolve 4 lbs. of sulphate of copper in 5 gallons of water in a barrel capable of holding 40 gallons, then make up to 35 gallons.

N.B.—(*Iron or zinc vessels must not be used.*)

(2) Dissolve in another vessel in 5 gallons of water 5 lbs. of washing soda (previously broken up into small pieces if necessary).

(3) When the soda is *completely* dissolved, add (2) to (1) stirring vigorously meanwhile.

N.B.—(Both Copper Sulphate and Soda should be of fully 98 per cent. purity.)

Where smaller areas are to be sprayed, barrels, capable of holding 10 gallons may be used; in that case the quantities of copper sulphate and soda given above should be reduced each to $\frac{1}{4}$, namely, 1 lb. of sulphate of copper and $1\frac{1}{4}$ lbs. of washing soda.

Burgundy mixture should be bright blue in colour and should not settle for a considerable time. Experience has shown that the precipitate remains longer in suspension and adheres better to the foliage when the mixture is made up in the above manner than when the soda is added to a concentrated solution of copper sulphate. The fungicide should be used in a *fresh state* and in no case should it be applied more than 10 hours after it has been made.

Both copper sulphate and washing soda dissolve slowly in cold water. The preparation of the solutions may be hastened by dissolving the copper sulphate and soda each in a gallon or so of hot water and making up the quantities indicated above by the addition of cold water; but before the solutions are mixed with one another they should be allowed to become cold. In order to save time, the copper sulphate and soda may be dissolved beforehand, but after the one is added to the other, the mixture should be used with as little delay as possible.

Sulphate of copper is poisonous, therefore the vessels in which the copper compounds have been prepared should not be used for the preparation of food.

The above formula gives what is known as 1 per cent. Burgundy mixture, *i.e.*, 1 per cent. of Copper Sulphate is used in its preparation. The use of Burgundy mixture of double this strength, *i.e.* 2 per cent., is sometimes advocated, but results indicate that there is little to be gained by the application of the stronger fluid. The Irish Department of Agriculture has for a number of years carried out trials as to the relative merits of 1 and 2 per cent. Burgundy mixture. For the five years 1911-1915 the average yield per acre sprayed with the 1 per cent. mixture was 12·24 tons as against 12·25 with the 2 per cent. strength, the weights of *healthy* tubers being respectively 11·72 and 11·84 tons. In some years the 1 per cent. mixture gave

better results than the other. Although the average yield during the five years was fractionally better when the 2 per cent. mixture was used, there is not sufficient difference to warrant the Food Production Department advising the use of the stronger fluid, especially at a time when copper sulphate is much increased in price. In particularly wet districts, however, it may be advisable to use the 2 per cent. mixture. During 1917 good results were generally obtained with the weaker solution.

VI.—INSTRUCTIONS FOR MAKING BORDEAUX MIXTURE.

This mixture should be made up in the following proportions:—

Copper Sulphate	... 4 lbs.
Quick Lime (freshly burnt lumps) ...	... 2 lbs.
Water	... 40 gallons.

The copper sulphate should be dissolved in 35 gallons of water in a barrel. The lime should be placed in a separate vessel and slaked *slowly*. This is best done by adding only the amount of water which the lime can absorb. After the lime is thoroughly slaked, more water should be added gradually, stirring all the time, to make up to five gallons. It should then be strained through a fine sieve and added to the solution of sulphate of copper, the contents of the barrel being vigorously stirred during the mixing. Other precautions should be taken as advised for making Burgundy mixture and the mixture should be tested with red litmus paper; if the paper does not turn blue more milk of lime should be added until the blueing of the litmus paper indicates that the right proportions have been obtained. The above formula is for a 1 per cent. Bordeaux mixture and to make the stronger, 2 per cent. solution, double the quantities of copper sulphate and lime are required to the same amount of water. There is, however, little to choose, as regards fungicidal power, between a one and a two per cent. mixture.

VII.—APPLICATION OF THE SPRAYING MIXTURE—KNAPSACK SPRAYING MACHINES.

For small areas Burgundy and Bordeaux mixtures are best applied by means of a knapsack machine, which must be provided with a nozzle that throws a fine misty spray. The person spraying should aim at covering the under surface as well as the upper surface of the leaves as both sides are liable to infection. It is a mistake to apply too much fluid. On no account should the plants be "washed." All that is required is that, after spraying, the thinnest possible covering of the fungicide should be spread evenly on the leaves; this is best done by maintaining a high pressure in the spraying machine.

For the first spraying, about 120 gallons of the fungicide per acre or $\frac{3}{4}$ gallon per rod, pole or perch should be used, and for the second spraying, about 160 gallons per acre or one gallon per rod, pole or perch.

If a knapsack machine is not available, a syringe fitted with a nozzle which throws a mist-like spray may be used on small plots. Large fields of potatoes on the other hand must be sprayed by a horse-drawn machine. All spraying machines should be kept in good condition by oiling frequently the important working parts, and by careful washing out after use.

VIII.—DATES FOR SPRAYING.

It is important to remember that the first spraying should be done before the disease appears, but in view of variations in the time of appearance of "blight" in different years and in different parts of the country, it is obvious that the dates for spraying must vary with the season and the district. Thus, potatoes in the south-western counties should be sprayed earlier than those in the east and north. The condition of the haulm must also be taken into account, it being difficult and sometimes impossible to spray effectively when the haulm is far advanced in growth. When possible, the spraying should be done as soon as dry weather sets in after the first wet spell occurring at or about the dates given below. The best results are obtained when spraying is done during dry weather. It is better, however, to spray even when light rain is falling than to delay the operation too long in expectation of dry weather. Spraying should in no case be done in very wet weather, and if heavy rain falls before the spraying fluid has dried on the foliage, thereby washing off much of it, a further application should be given as soon as conditions permit. Spraying should be carried out preferably in the early morning or evening, and not when a hot sun is shining.

In an average season an approximation to the following dates for the first spraying of second early and main crop potatoes will probably be satisfactory.

Cornwall	June 15th—end of June. *N.B.*—Spraying should be done the last week of May for early varieties in the Penzance district and the first week of June in other forward districts of Cornwall, Devon, and the Isle of Wight.
Devon	
Dorset	
Isle of Wight and Hampshire ...	
Somerset	
S.W. Wales	
Glamorganshire ...	July 1st—July 8th.
Gloucestershire ...	
Monmouthshire ...	
Sussex	
Wiltshire	
Berkshire	July 8th—July 15th.
Herefordshire ...	
Kent	
Oxfordshire	
Surrey	
Worcestershire ...	

Remainder of the country ... July 15th—July 31st.

(In the north-eastern counties spraying should usually be deferred until the last week of July.)

The second spraying should generally be done about three weeks after the first. It will serve to cover the new foliage and to protect more completely that already sprayed. In the south-west of England it will often be found advisable to spray a third time, and this applies also to other districts in wet seasons when heavy rains are frequent.

Even when blight has broken out and the potatoes have not previously been sprayed, it is not too late to spray; for by so doing the rate of spread of the disease will be checked and the damage to the crop reduced, though the protection from disease will usually be less complete than when spraying was done earlier.

There is some difference of opinion as to whether second earlies as well as main crop varieties should be sprayed. Where the disease is apt to appear early and to be specially virulent, as in the western half of the country, it is certainly advisable to spray second earlies, but where the foliage of these varieties is on the point of ripening before the disease appears, it is not worth while to spray them. Second earlies, which are planted late or which are to be lifted late, should, of course, be sprayed.

In the Penzance district it may also be necessary to spray first early varieties, as in adverse seasons serious outbreaks of disease are apt to occur even in first earlies. In other parts of the country the haulm of early varieties may be affected by blight, but it is generally held not to be worth while to spray them, as the crop will usually be lifted before the disease affects the tubers, but it should not be forgotten that the disease developed on first earlies may spread from them to second earlies or main crop potatoes growing in their neighbourhood. First earlies, which have been planted late or which for any other reason are to remain in the ground some time after the appearance of disease, should be sprayed.

IX.—THE ADVANTAGES AND DISADVANTAGES OF SPRAYING.

The advantages derived from spraying have already been described. They are:—

(1) Prevention or delay of outbreak of the disease.

(2) Reduction of the virulence of the attack.

leading to

(3) An increased yield and a smaller amount of disease in the tubers.

As has already been stated, potato spraying has been practised for many years both abroad and in the British Isles, and the results of spraying show an overwhelming preponderance of evidence in favour of this operation. In the same way the results which have been obtained during the past year show that in the large majority of cases spraying produced beneficial

results. A striking example of protection from disease conferred by spraying is given in Fig. 4.

An analysis of the reports received during 1917 shows that in the larger majority of cases spraying produced beneficial results. In some cases, however, the reports state that spraying was either useless or actually harmful. Of these adverse results it is possible to show that some were due to inexperience in spraying. Sometimes the spraying material, instead of being used immediately whilst it was fresh, was allowed to stand too long before it was used. In other cases the directions for making the spraying fluid were not followed, and sometimes the spraying was not done until the haulm had already made very considerable growth or until after the disease had appeared, owing to the earliness of the season and to the machines and chemicals being delivered late.

When, however, every allowance is made for these remediable defects in methods of spraying, the fact remains that in a certain number of cases competent observers reached the conclusion that spraying was not beneficial. It is, therefore, important to endeavour to ascertain what are the causes leading to the remarkable fact that, although in the majority of cases spraying resulted in marked benefit to the crop, in some cases it failed to produce this result.

Before considering this question it may be worth while to refer briefly to certain opinions adverse to spraying which are undoubtedly groundless.

It is claimed sometimes that spraying is poisonous to bees. There is no ground for this statement. Many varieties of potatoes fail to flower, others drop their flowers before the blossoms open. Among those that do flower, not a few varieties bear blossoms the stamens of which do not burst, and hence produce no free pollen which insects might gather in lieu of nectar. Neither do bees visit potato flowers in any considerable numbers, nor, if they did, would the small amount of fungicide deposited in the flower be likely to injure these insects.

Whilst on this subject, however, it is worth while pointing out, although it has nothing to do with the matter under consideration, that it has been shown on several occasions that if the flowers of the potato are picked off consistently the yield of tubers is increased. This would not be practicable on a large scale, but it is possible where small areas of potatoes are grown.

Another statement frequently made and baseless is that spraying spoils the keeping qualities of potatoes. The opposite is the truth. For, as already mentioned, the tubers of sprayed potatoes are less liable to disease than are those of unsprayed potatoes, and diseased tubers are apt to rot in store.

Again it is sometimes asserted that sprayed potatoes turn black on cooking; spraying has no influence on the colour which cooked potatoes assume. The blackening is a peculiarity due to the fact that certain varieties of potatoes sometimes contain a chemical substance which when exposed to the air is oxidised and forms a black pigment.

A certain number of complaints from inexperienced growers take the form that after spraying, the lower, yellow leaves fall off. This is no disadvantage; the yellowing leaves indicate by their colour that they are already moribund and their fall is no loss to the plant.

Yet another objection is that seed taken from sprayed potatoes is unsatisfactory. Again this opposition has no basis in fact. Indeed, wherever disease has appeared, seed from sprayed potatoes is likely to be less diseased and hence to be better than seed from unsprayed potatoes. Moreover, it is a well established fact that the best seed is obtained from *immature* tubers, and one of the effects of spraying is to prolong the growth of the haulm, and hence to delay the maturing of the crop.

Another of these minor objections may be mentioned. It is often stated that when potatoes are intercropped there is a risk of food plants being poisoned. In the case of ordinary inter-crops of the cabbage tribe the danger is negligible; at the time of spraying the plants are not far advanced; the rains subsequent to spraying will gradually wash away any deposit which may be on the leaves, and the copper, if any, which remains will be confined to the outer leaves which are not used. At the same time it need not be said that every precaution should be taken before these plants are prepared for food. If no copper is to be seen on them, no danger is to be feared. In the case, however, of food plants which are used in the raw state, as for example, lettuce, there is an element of danger and such crops should not be used for inter-cropping with potatoes.

Turning now to the more weighty objections which are raised, the first that deserves attention is the statement that the ripening of the crop is delayed owing to the haulm remaining green for a longer time. The statement is correct. The copper sulphate used in spraying, exercises a preserving influence on the haulm and in some seasons, with the latest varieties, this might possibly be a disadvantage; on the other hand in the majority of cases and seasons the extension of the growing period means an increase in the yield and is therefore a decided advantage rather than a disadvantage.

The most serious objection which has been brought against spraying is that it may lead to scorching and falling off of the leaves. There is evidence that this result occurred during the past season, but the cases of scorching or partial defoliation were comparatively rare.

An examination of the records indicates that the scorching and other damage to the foliage, where it occurred, took place under one or other of the following conditions:—

(1) In potatoes growing under bad conditions of cultivation as, for example, in insufficiently drained, shallow, or light soils.

(2) Where mistakes were made in making up the mixture, particularly by using wrong proportions of the ingredients.

(3) In cases in which frost occurred after spraying had been done; for example, in 1917, where spraying was done in June in northern districts late frosts occurred after the date on which spraying was done. It appears to have been undoubtedly the case that sprayed foliage suffered more severely than unsprayed. The explanation is obscure, but it should be noted and those who grow potatoes in exposed districts will be well advised to delay spraying until the danger of late frosts is past. It may be mentioned also, that in some places on the north-east coast, potatoes sprayed during the day were scorched the same night by the inopportune occurrence of a cold sea-fog.

(4) Lack of success in spraying was also traced to the fact that the sprayed plants had previously been attacked by aphis. There is no doubt but that plants so attacked suffer considerable damage from spraying, nor is this remarkable when it is remembered that the aphides made innumerable punctures in the leaves, and hence the spraying material on such leaves has ready means of access to the delicate internal tissues of the plant. It therefore follows that if it has been impossible to protect the plants from the attacks of aphis, they should not be sprayed with Burgundy or Bordeaux mixture. It is possible that in such cases a "dry" spray might be found beneficial. It is noteworthy that in 1917 aphides were quite exceptionally prevalent upon potato foliage—especially in the Midlands, and that no such attack had been seen on potatoes for many seasons.

(5) Lastly, it appears to be an undoubted fact that potato crops grown in the neighbourhood of factories and in an atmosphere containing acid fumes may be adversely affected by spraying. The reason for this is not clear. It may be due to some chemical change brought about by the action of the acid fumes on the spray mixture. On the other hand it has been suggested that the potato foliage in many of these situations is less vigorous than when it is growing in clearer air and hence is less able to resist the penetration into its tissues of the poisonous ingredients of the spray fluid. Possibly it may be proved that a "dry" spray will produce the advantages of spraying without the disadvantages. This, however, must not be taken as a recommendation of "dry" spraying, for although various substances in powdered form have been used in different parts of the country, and although the results are said to have been beneficial, the experience

at the disposal of the Department is not sufficient at present to enable it to make a general recommendation on the subject.

Of the serious objections which have been raised, the first two are remediable: by ensuring better cultivation and by making up the spray fluid accurately, the damage may be prevented.

The third objection, damage by frost after spraying, can only be prevented by delaying spraying until risk of frost is over.

The last-mentioned cases of potatoes affected by aphis and of potatoes grown in a fume-laden atmosphere are serious, and must be taken into consideration by those who are contemplating spraying.

In concluding this summary of objections, it is important to point out that, as described in some detail later on, the potato is subject to many diseases, of which "blight," although in many ways the most important, is only one. Now it cannot be too strongly insisted upon that spraying is a preventive of blight, and not of other potato diseases.

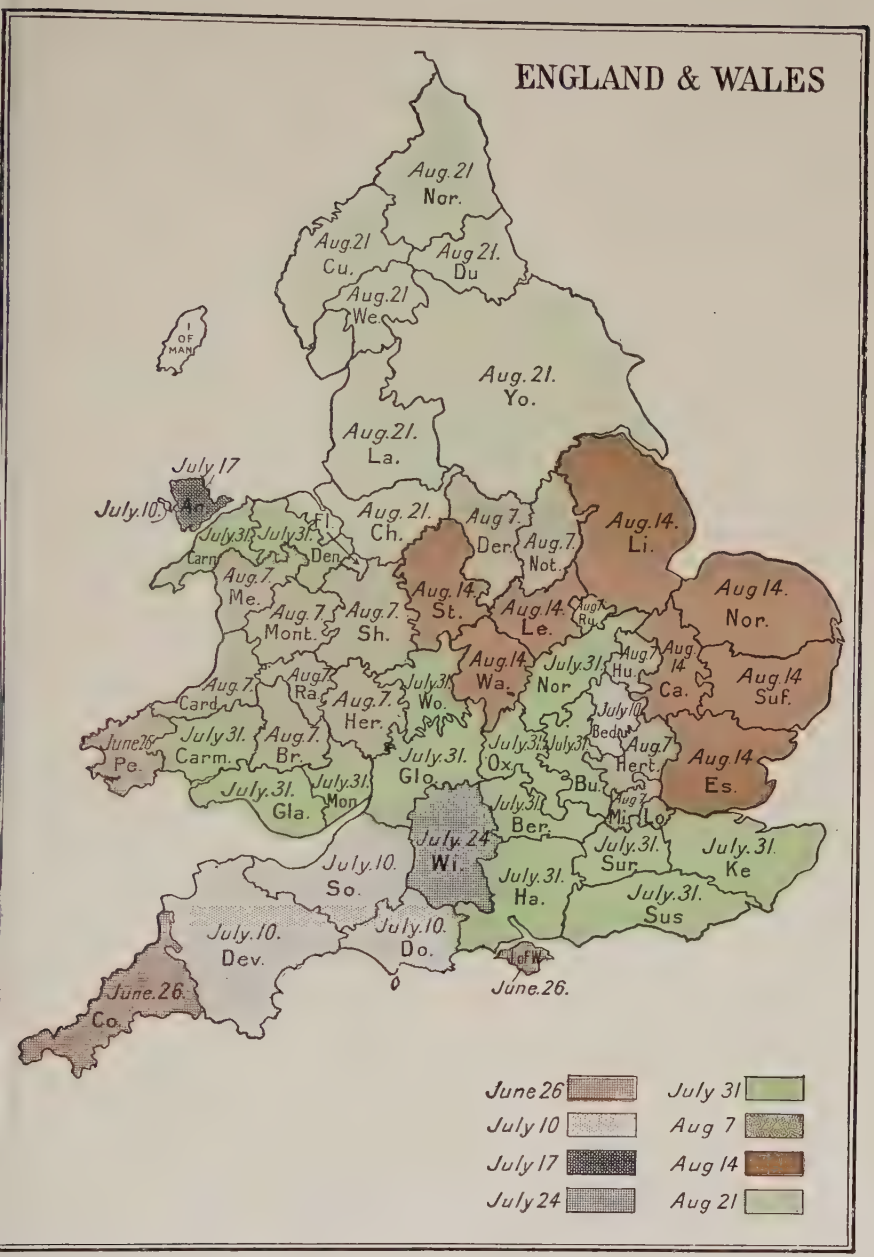
In this connection it may be mentioned that during the past year the disease known as "Blackleg" was common in certain districts of the country. This disease is already in the seed when it is planted. It is due to a bacterium, and not to the fungus which causes "blight." Spraying is useless to prevent it, and in not a few instances when the advanced symptoms of "blackleg" appeared, viz., blackening of the lower part of the stem and dying of the leaves, it was assumed erroneously that the disease was "blight," and that spraying was therefore useless.

X.—OTHER MEANS OF REDUCING THE DAMAGE CAUSED BY "BLIGHT."

(Seed Selection; Planting Distances; Earthing-up; Treatment of Diseased Haulm; Lifting and Storing.)

The outbreak of an attack of "blight," like that of any other disease caused by living germs, depends first, on the presence of the organism causing the disease, and second, on the power of that organism to gain an entrance to and grow into the tissues of the plant.

The most certain method of preventing this disease would be to cultivate varieties which resist its attack. In the case of certain other diseases, as, for example, wart disease (black scab) of potatoes, immune varieties have been discovered, and are now in general use in infected areas. By planting these immune varieties the grower is able to secure a heavy crop and to be sure that the crop will not suffer from wart disease. It must, however, be clearly understood that a variety which is immune from one disease, as, for example, wart disease, is not necessarily immune from another, and in point of fact the varieties immune from wart disease show all degrees of susceptibility to "blight."



Note:—
The Dates refer to the ends of Weekly Periods during which Potato "Blight" first appeared in the respective Counties, with the exception of the Period ending June 26th, which includes all outbreaks previous to that date. (i.e. from end of May.)

FIG. 3.

Sprayed. FIG. 4. Sutton Satisfaction Potatoes *Unsprayed.*

Unfortunately, the grower is not able at present to plant varieties immune to "blight," for although the Irish Department of Agriculture has discovered that certain varieties of potato, *e.g.*, Champion II. and Shamrock, are either immune or highly resistant to "blight," these varieties are often deficient in some important character, such as quality, cropping power, or appearance. Little can be said about the relative susceptibility to "blight" of the many varieties of potatoes grown on a large scale, because the degree of susceptibility depends largely upon the particular stock of the variety and upon the locality in which it is grown. In the absence, therefore, of varieties which are immune to "blight," and at the same time are profitable commercially, the potato grower for the present must rely on other means of prevention.

Before describing the means of reducing the danger of loss by "blight" other than by spraying, it will be useful to point out that, as every good cultivator knows, an outbreak of disease depends not only on the presence of the agent causing the disease, but also on the healthiness of the plant. It therefore follows that the grower has at his hand the means not, it is true, of preventing entirely but of reducing the risks and severity of an outbreak of disease. These means are:—

(1) Choice of clean and vigorous seed (sets).
(2) Good methods of cultivation.

(1) *Choice of Seed.*

The two most important points to be borne in mind in choosing and planting seed (sets) are:—

(*a*) The selection of a good stock of a good variety suitable to the soil; and
(*b*) care in securing that diseased sets are not planted.

(a) *Selection of a Good Stock.*—It is a well-known fact that if seed tubers are taken from plants grown in some parts of England, especially on the light soils of the South, the plants which that seed produces are lacking in vigour, and whether they suffer from disease or not, give an inferior yield. On the other hand, it is equally well-known that if Scotch or Irish seed—that is, seed obtained from the good potato-growing districts in Scotland or the North of Ireland—is used, the plants are vigorous and the yield is high.

Similarly, seed from once grown Scotch or Irish potatoes—that is, the produce of seed raised in Scotland and Ireland and grown for one year in England—also gives strong plants and good yields, provided that the plants were grown in one of the good potato districts as, for example, Lincolnshire, parts of Cambridgeshire, and Yorkshire.

Inasmuch as it is good common sense that the healthier the plant the less liable is it to suffer from disease, it follows that Scotch or Irish seed, or once grown seed from Scotland or Ireland, would be less likely to suffer from disease than would

plants raised from own-saved seed. Therefore, unless a grower has absolute proof, from long experience, that his own raised seed gives high yields of healthy tubers he should plant only Scotch or Irish seed. As an example of an actual test of the yields from Scotch or Irish, as compared with English seed, the following figures, taken from the report of a trial carried out by the Royal Horticultural Society at Wisley, Surrey, may be given :—

	English Seed.	Scotch Seed.	Irish Seed.
	lb.	lb.	lb.
Yield of 20 sets of Edward VII.	63	71	—
" " " Arran Chief	48	76	76
" " " .. "	61	78	—
" " " Golden Wonder	51	78	—
" " " White City	57	77	—

It is also a well-established fact that immature tubers make better sets than well-matured tubers, and therefore it is good practice, where home-grown seed is to be used for planting, to lift the more vigorous plants before the haulm has completely died down and to use the tubers of these plants for seed. Tubers to be used for seed purposes should be greened by exposure to the light for several days, whereas those which are to be used for food should be stored as soon as dry. (See *Board of Agriculture Leaflet No.* 299, " The Storage of Potatoes and Other Vegetables for Winter Use.")

The best sets are obtained from tubers about the size of a hen's egg and weighing about 2 ozs. Larger seed gives a slightly increased yield but is not economical owing to the greater weight required for planting. Where large tubers are alone available for seed purposes, they should be cut into several pieces and the cut surfaces rubbed in dry plaster of Paris and the pieces boxed. Lime is sometimes recommended but plaster of Paris gives better results. In cutting tubers it should be remembered that sets taken from the heel end give poorer plants than those taken from the rose end, and hence the cuts should be such as to secure several pieces each of from 1½ to 2 ozs. in weight from the rose end of the potato, bearing in mind that each piece must have at least one eye.

(*b*) *Selection of Clean Seed.*—Growers who cultivate small breadths of potatoes can do much to prevent " blight " by taking care to plant seed which is free from disease. In order to ensure this, potatoes, even those of the main crop, should be boxed and sprouted. For this purpose the sets should be put in boxes of convenient size, either the ordinary potato-sprouting boxes or, failing those, any convenient shallow, wooden or wicker receptacles, stored in a dry, frost-proof place and exposed as fully as possible to the light. By this means sturdy shoots are obtained

which are less likely to be broken at planting time than are the weaker or spindly shoots produced when tubers are sprouted in the dark. If, however, it is not possible to sprout boxed seed in the light the seed should none the less be boxed and sprouted, for even though the sprouting is done in the dark the yield is higher than from unsprouted sets. With care in planting, injury to the sprouts may be prevented. The sets should be placed in the boxes in single layers with the rose end, that is the end where most of the eyes are, uppermost.

The sets should be put to sprout at least three weeks, and preferably five or even more, before planting. If this is done the sprouts should be from half an inch to an inch long at planting time, and such sets when planted give yields larger than those taken from unsprouted sets by so much as 28 lbs. to the square rod. Another advantage of boxing is, that it enables the grower to reject diseased and poor sets.

When planting the sets, two sprouts only should be left, as it has been shown that thereby the best results are obtained.

Those tubers which do not sprout at all or which give only thin and weak shoots should not be planted. Moreover, if the tubers belong to a variety which does does not suffer by being cut, they may be cut at planting time by slicing off a portion of the heel end, and any tubers which show signs of disease, hollow spaces, or brown or black patches in the flesh, should be rejected.

Steeping the sets in a fungicide before planting is of no use as a means of preventing "blight."

(2) *Methods of Cultivation.*

(*a*) *Planting Distances.*—Next only in importance to the choice of good seed as a means of reducing the risks from "blight" is the practice of good methods of cultivation. Among these methods, sufficient space between the rows and between the plants must have consideration. The width of the rows and the distance from plant to plant naturally varies according to the soil and variety but, from the point of view of preventing the rapid spread of "blight," it is certain that wide planting is advantageous, and many good growers recommend a distance of 3 feet between the rows and 15 to 18 inches from plant to plant. It is true that closer planting will at times give a larger yield on certain soils but it also increases the risk of disease.

(*b*) *Earthing up.*—By earthing up the plants thoroughly the risk of infection of the growing tubers is reduced, and wherever possible it is recommended that the earthing up should be done in two stages. If the development of the haulm is not too advanced the second earthing up should be deferred until shortly before the time at which disease is likely to make its appearance in the particular neighbourhood. (*See above.*)

(*c*) *Manures.*—The potato is a crop which grows well even though the ground is only lightly treated with farmyard manure. It responds well to artificial manures. A good system of manuring consists in the application just before the time of planting of a mixture of superphosphate of lime (5 parts) and

sulphate of ammonia (3 parts) at the rate of 3-4 oz. to the square yard. If sulphate of ammonia is applied after the shoots have come above the ground, it should be mixed with soil so that the growing plant does not come in contact with it. The addition of a small quantity (1 oz. to the yard run) of wood ashes as a dressing to the soil before the sets are planted is also to be recommended; for the potash combined in the ashes helps to produce vigorous growth.

(*d*) *Treatment of Diseased Haulm.*—If blight appears to a serious extent in the foliage at a time when it is too late to spray, it is advisable to pull or cut off the haulm before the majority of the spores fall to the soil—main crop tubers being left for a time to ripen naturally in the ground, for by so doing the risk of the tubers becoming infected is reduced. The potatoes should be dug as soon as their skins have set, because after this takes place there is a likelihood of their growing out, particularly if wet weather intervenes. The haulm should be burnt as soon as possible, and in no case should be allowed to lie on the ridges.

(*e*) *Lifting and Storing.*—(See *Board of Agriculture leaflet No.* 299, "Storage of Potatoes and other Vegetables for Winter Use.")

XI.—OTHER IMPORTANT DISEASES OF THE POTATO AND THEIR SYMPTOMS.

(*Wart Disease; Black-leg; "Rust"; Leaf-curl; Corky Scab; Common Potato Scab; Dry Rot; Caterpillar Injury.*)

Wart Disease or Black Scab (see *Board of Agriculture leaflet No.* 105).

Affected tubers show irregular outgrowths which look like dirty pieces of cauliflower or the whole tuber may be similarly transformed. This is the most serious disease of the tubers, and its presence must be notified to the Board of Agriculture and Fisheries. The disease is caused by the fungus *Synchytrium endobioticum*. *Immune varieties* must be grown in land infected with Wart Disease.

Black-leg or Black-stalk Rot (see *Board of Agriculture leaflet No.* 117).

The foliage becomes yellowish and the base of the haulm turns black and subsequently becomes rotten, after which the plant dies down completely; the tubers also may be affected. This disease—which is most prevalent during June and July—is caused by a bacterium (*Bacillus melanogenes* or *Bacillus phytophthorus*).

No remedy is known. The disease passes from the seed into the growing plant. Tubers from plants affected with this disease should not be used for seed.

"Rust."

This is the popular name of a disease especially prevalent in the west of England and characterised by rusty and enfeebled foliage. It is largely due to the use of poor seed, and when dry weather prevails early in the season, the crop is frequently crippled.

Rusty foliage and a stunted habit of growth are sometimes associated with a disease of the haulm caused by the fungus *Verticillium albo-atrum*. Change of seed and care in seed selection should ensure the crop against attack by "Rust."

Leaf-curl (see *Board of Agriculture leaflet No.* 164).

As the name implies, plants thus affected have curled leaves and are often stunted in growth. Plants seriously affected by leaf-curl often give little or no yield. No remedy is known, but if good seed is used the disease is not likely to prove troublesome. Sprouting prior to planting is helpful for, as a rule, sets which produce strong sprouts will grow into sturdy, fruitful plants.

Corky Scab (see *Board of Agriculture leaflet No.* 232).

Affected tubers are only partly deformed, the seat of infection by the parasite *Spongospora subterranea* being characterised by the presence of loose, corky *débris* which does not usually penetrate deeply into the tuber. This disease is notifiable.

Common Potato Scab (see *Board of Agriculture leaflet No.* 137).

This scab is exceedingly common, but as it is purely superficial and does not affect the quality of the tubers it can generally be ignored though scabbed potatoes should not be used for seed.

Dry Rot (see *Board of Agriculture leaflet No.* 193).

This disease, which leads to shrivelling and collapse of the tubers attacks them mainly in storage. It is caused by the fungus *Fusarium coeruleum*. (For best methods of storage see *Board of Agriculture leaflet No.* 299.)

Caterpillar Injury.

During 1917 the caterpillar of the Rosy Rustic moth, *Hydroecia micacea*, frequently attacked potato haulm, penetrating the stem and eating the inner tissues, thus causing the haulm when nearly full grown to collapse. Ordinarily the caterpillars feed upon coarse weeds, and the breaking up and cultivation of land which had lain derelict for many years and had been the home of the insects destroyed their natural food, so that the caterpillars were driven to the potatoes. Proper soil cultivation will prevent insect hibernation, so that no future trouble to any extent need be feared by good gardeners.

Arrangements for Potato Spraying during 1918.

For 1918 the distribution of knapsack spraying machines and chemicals will be left in the hands of manufacturers and retailers.

Knapsack Spraying Machines.—The trade has arranged to manufacture certain types of knapsack spraying machines which, while retaining the distinctive marks of individual firms, will be made to a specification issued by the Food Production Department. The manufacturers have undertaken to supply these machines at a fixed price.

It is essential that all those who are not already provided with knapsack spraying machines shall place their orders without delay so that the machines will be delivered early in 1918.

Chemicals.—The price of copper sulphate in 1918 will be controlled in such a way that purchasers ordering for delivery early in the year will have a distinct advantage over those who defer their orders.

There will probably be a shortage of soda crystals (washing soda) in the coming season, hence it is *absolutely essential* that early steps shall be taken to secure the necessary supply for spraying purposes.

Lectures and Demonstrations.—With the object of spreading knowledge on the subject of Potato Blight and of providing instruction in spraying during the latter part of the winter and spring, a staff of lecturers has been appointed whose services will be available to Local Societies on application to the Food Production Department. These officers will give lectures, illustrated by lantern slides and drawings, on Potato Blight and its prevention. The services of these lecturers will be available also to assist Local Authorities and Allotment Societies in organising the spraying of the potato crop during 1918.

APPENDIX.

SUMMARY OF RECORDS OF RESULTS OF THE 1917 SPRAYING CAMPAIGN.

It is not proposed to issue a full report of the results of spraying the potato crop in 1917 for two reasons: 1. Although many reports have been received it has not been possible for the Officers of the Food Production Department to check many of the results and thereby ensure that all these reports were of equal value; 2. It is proposed to arrange for exact and extensive records to be kept during the coming year. This should result in the accumulation of a large body of evidence of unchallengeable value.

The following is an analysis of 305 representative reports received by the Food Production Department:—

(1.) Number of reports which indicate that decided benefit accrued from spraying 213

(2.) Number of reports of an indefinite character, spraying being apparently neither beneficial nor harmful 66

(3.) Number of reports in which the results of spraying were considered to be harmful 26

Officers of the Food Production Department closely investigated as many as possible of the reports in which it appeared that spraying had been followed by injurious results and in the majority of cases the damage was definitely traced either to errors in making up the spraying fluid, to the influence of acid fumes in the atmosphere, or to the fact that spraying had been done when the haulm was attacked by aphides (*see* also pp. 12 16)

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